Development Options for Mobile Offshore Base Technology

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ABSTRACT

A Mobile Offshore Base (MOB) is a very large floating platform comprised of serially connected modules. Previous ISOPE papers described the MOB research program, identified research spin-offs, and assessed technical feasibility in support of a military logistics mission. This paper highlights the most recent MOB technological advancements and explores applicability to building large floating platforms for other military and commercial missions. The paper also outlines specific technologies where additional research work would further reduce the risk of designing, building, and operating large floating platforms.

KEY WORDS: Semisubmersible, classification guide, hydroelasticity, stability, dynamic positioning, and connectors

MOBILE OFFSHORE BASE (MOB)

The United State's ability to stage and support military and humanitarian operations anywhere in the world depends on sustained access. However, long-term access to forward land bases including airfields and shipping ports can no longer be assured in areas of the globe where adequate host nation support is either not available or unsuitable. A sea base, positioned in international waters, could provide much of the same logistics support that several land bases currently provide.

As presently envisioned, a MOB is a self-propelled, floating, prepositioned logistics base that accepts cargo from aircraft and container ships and discharges resources to the shore via a variety of surface vessels and aircraft. The basic strategy is to maximize reconfigurability by deploying floating "building block" semisubmersible modules, like the one shown in Figure 1.

Each semisubmersible module consists of a box-type deck supported by multiple columns on two parallel pontoons. The decks, which store rolling stock and dry cargo, are all located above the wave crests. Liquids are stored in the pontoons and columns, eliminating most below-sea-level voids and thus minimizing greatly the danger of damage due to flooding.

When on site, the module is ballasted down so that the pontoons are submerged well below the surface wave zone. This condition minimizes

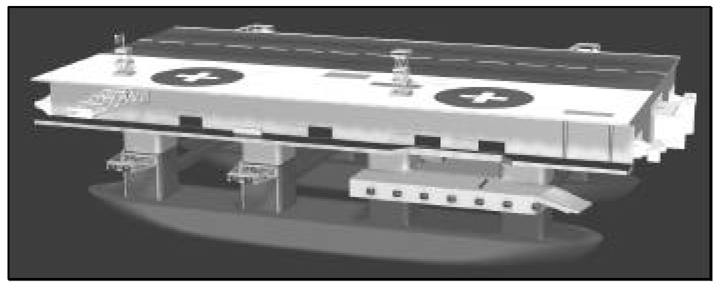

Figure 1. A Typical 305-meter-long MOB module for serially connecting to similar modules

the wave-induced dynamic forces, which in turn decreases the wave-induced motions of the deck. Under wave conditions where ships may be rolling upwards of 10 degrees, the semisubmersible hull will often be rolling less than 1 degree. This offers a great advantage over conventional ship hulls for open-ocean cargo operations.

When transiting between operational sites, the module is deballasted and travels with the pontoons on the surface. In this deballasted-up condition, the semisubmersible hull reduces form drag and can transit at high speeds on its narrow pontoons much like a catamaran.

Length is the most critical factor driving cost and technical risk for a MOB. Representing only a modest increase in risk over the current industry standard for large lifting semisubmersibles, a single MOB module, can support most missions. Operating concurrently in several world locations, each module can provide personnel housing, equipment maintenance, open-sea cargo transfer, and support for vertical-take-off-and-landing (VTOL) aircraft.

Conventional takeoff and landing (CTOL) aircraft requires runway lengths beyond that provided by one single MOB module. As needed, individual MOB modules could transit to a common location, and connect serially to form a runway as long as 2,000 meters. Runway lengths of 1000 and 1,800 meters are required for safe operation of C-130 and C-17 cargo airplanes, respectively (Polky, 1999). A CTOL-capable MOB raises concerns about unproven experience with high-strength connectors, long-crested waves and simulation tools to predict multi-module structural response.

Four major offshore contractors conceived MOB concepts to help establish feasibility, uncover technology risks, and support realistic cost estimating (Remmers et al, 1998). Each of the four concepts (See Figure 2)

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Figure 2. Possible concepts for a 1,500-meter-long multi-module MOB

deals uniquely with an innovative method for connecting the modules into a structure of sufficient length to form a long runway. Since the U.S. Department of Defense has not yet formally addressed the operational requirements for a MOB, it is not yet appropriate to recommend any particular concept. Instead, the science and technology strategy focused on identifying and delivering a design guide and complementing tools applicable to the full range of possible platform configurations and sizes (Remmers & Taylor, 1998).

MOB TECHNOLOGY

The process of designing MOB platforms helped identify a number of critical risk areas associated with MOB feasibility (Zueck et al, 2000). With guidance from a working group of designers, researchers and operators, the American Bureau of Shipping prepared a preliminary MOB Classification Guide (ABS, 1999). This Guide provides a reliability- and performance-based design process addressing structural integrity and hydrodynamic safety of interconnected MOB modules.

To improve the accuracy of the design/analysis tools that compliment the Guide, several hydrodynamic and hydroelastic computer simulation models were advanced and validated (Zueck et al, 1999). These design tool development efforts improved the accuracy for computing the hydrodynamics, stability, structural life expectancy and survivability of large floating platforms of single modules and connected MOB platforms.

A nonlinear time-domain hydrodynamic model was advanced for computation of the wave field around a MOB semisubmersible hull (Weems et al, 1999). To assure hydrodynamic stability, a new method to compute dynamic rather than static stability was developed (Falzarano et al, 1999). In addition, hydroelastic computer codes were modified for simulating the coupled wave field/structural response of large floating platforms (Kim et al, 1999). These new computer simulation tools still require validation against data from model experiments, such as the hydroelastic test sponsored by MOB (See Figure 3).

The hydroelastic compliance of the hull and the connectors is important for reducing the size of the design loads to assure structural integrity in extreme metocean conditions. Since a MOB platform would operate in many areas, it was necessary to obtain suitable metocean descriptors for representative sites around the world. Since measured metocean data useful for ocean platform design is generally unavailable, the MOB program generated hindcast metocean statistical databases for 22 representative sites around the globe and for 25 major typhoons (Pawsey and Manetas, 1999).

Because of the long length of the longest anticipated MOB platform, a MOB design methodology must define and incorporate a spatial view of the metocean environment to assure safe survival. For example, according to recent measurements partially sponsored by MOB, hurricanes and typhoons are known to be capable of generating waves with (at least) a 1-kilometer long crest and an 18-meter height.

The global response of the MOB to metocean conditions is highly dependent on the characteristics of its inter-module connectors. Some manufacturing technologies, such as steel plate thickness and elastic fenders, are not easily scaled up to meet the large load capacities required for connecting MOB modules. As a result, major concept designers have chosen to reduce these load capacity requirements by providing more flexibility in the connector.

A multi-module dynamic positioning system is also required for propelling, assembling, disassembling, and stationkeeping the connected MOB and/or its separable modules. Fortunately the cruise industry is currently pioneering the development of large horsepower azimuthing thrusters that are ideal as propulsion hardware for the MOB.

Advanced nonlinear control software, that can coordinate up to eight thrusters located on each of up to six MOB modules, has been developed and is now being physically tested (Girard and Hedrick, 1999). This software can uniquely prevent damage while docking, adapt to mechanical failures, and counter spatially varying environmental disturbances along the length of the serially connected floating modules. This new type of multi-body dynamic positioning control is being validated by exercising it on a representative sub-scale experiment consisting of three semisubmersible modules as partially depicted in Figure 4.

The specifics of MOB technological achievements are published in the technical literature (Remmers et al, 1999). In addition, over 350 documents generated by the MOB program are available at the Internet site, http://mob.nfesc.navy.mil.

Figure 3. Hydroelastic model tests for MOB provided data for validating next-generation structural response models.

Figure 4. One module of a multi-module, dynamic positioning test to demonstrate nonlinear control software

CONSTRUCTABILITY AND SURVIVABILITY

At approximately 300,000 metric tons of displacement, even the smallest of the proposed MOB semisubmersible modules is an order of magnitude larger than any existing semisubmersible hull. However, fixed structures of comparable size have been built, and the techniques for offshore assembly of major fabricated assemblies into finished platforms have been demonstrated. A risk-based constructability analysis (Bender et al, 1999) shows that MOB modules can be built in the US using a combination of onshore and offshore facilities.

A properly located explosion will "break the back" of a normal ship, reducing hull girder strength to a small fraction of that needed for even calm water. Semisubmersible hull forms are far more resistant to this type of attack, since localized pontoon buckling does not directly affect the structural decks. Most of the column and pontoon boundary tanks are used for ballast or fuel; hence puncture may not even substantially change the level of submergence.

Stored munitions can detonate from accidental and hostile action. Traditional naval vessels cannot typically operate, and quite often sink, after a magazine explosion. However, the MOB's physical size and arrangement provide the potential to meet tougher safety requirements through a combination of physical separation, non-propagation walls, and venting explosive pressures downward below the deck.

OPERATIONAL UTILITY

A MOB-type sea base would be a totally new type of military and humanitarian support asset that would directly support the Navy's new focus on Operational Maneuver From The Sea. A sea base would be a source of sustainment that would eliminate a major footprint ashore, thus easing the burden of force protection (Troshinsky, 1999). It would create an at-sea location for the difficult break-bulk operations needed to support highly mobile and ultra-light shore units. A sea base could move forward, removing the historical concern of long logistics lines. It could move from region to region, wherever personnel and materiel are needed, minimizing the irretrievable costs of building land bases.

Could a collection of conventional ships serve effectively as a sea base? Most cargo for sustainment of military forces now comes tightly packaged in container ships and airplanes, which means there is no suitable room for equipment servicing and assembly once it arrives on-site. Second, because conventional ship hulls roll in the presence of even minor ocean waves, containerized cargo cannot be reliably unloaded on a sea base consisting of conventional ships. Third, conventional aircraft carriers have runways far too short to accommodate the landing of conventional fixed wing cargo planes.

In contrast, a MOB provides a large platform for marrying troops to their materiel at a location very close to the area of concern but far enough at sea to be easily defended (Zueck and Taylor, 2000). In addition, it would have ample space for storing cargo, unpacking supplies, maintaining equipment, providing medical services, training troops, berthing personnel, and providing rest and relaxation. A semisubmersible hull insures small motions for unloading container ships, discharging resources to the shore, and reloading vertical-launching vessels. A CTOL-capable MOB is long enough to land all kinds of aircraft, allowing critical cargo and personnel to arrive just prior to an operation. Positioned just over the horizon, a MOB greatly reduces the threat inherent to conventional use of land bases.

An evaluation of transit speed requirements have shown that a speed of 12 knots over the water is generally adequate for meeting transit requirements for a sea base. In fact, 15 knots is easily achievable using the power available from MOB's robust dynamic positioning system.

MOB is intended as a logistics facility that directly supports existing naval assets, including aircraft carriers. In a "tactical aviation support" role, a MOB could operate as a divert field for damaged aircraft, a re-supply field for new aircraft, and a training field, thus allowing aircraft carriers to reach their highest level of readiness.

CARGO THROUGHPUT

A primary mission for the MOB is to store and transfer cargo as a logistics facility. The effectiveness of open-sea cargo transfer depends heavily on the high relative motion between the transferring vessels. Since a large semisubmersible like MOB does not move significantly, open-sea cargo transfer to and from large vessels is much easier. However, waves radiating from the large semisubmersible columns of a MOB can hinder cargo transfer to and from smaller vessels (Lundberg & Grant, 1999). A solution is to create a protected area by lowering wave barriers between the columns of the MOB. Upon completing cargo transfer operations to small vessels, the barriers are raised to reduce the loads generated during extreme storm conditions.

A suite of performance evaluation modeling and simulation tools are now available for quantifying how well the MOB satisfies given mission requirements (Brackett and Murdoch, 2000). These models include an operational availability model, a cargo transfer rate model, and a preliminary air operations model. The operational availability model (Jha et al, 1999) evaluates MOB concept performance on the basis of mechanical and structural reliability of the platform and its subsystems against environmental conditions and mission requirements.

The cargo transfer rate model (Cybulsky and Currie, 1999) estimates the transfer rate for both containerized cargo and rolling stock by simulating the transfer of containers to and from cargo vessels in the wave field alongside the MOB. The air cargo transfer model simulates the arrival, loading, fueling and transit of cargo aircraft from a sea base to its destination. The basic architecture and much of the logic in these models is useful for evaluating a wide range of alternative single or multi-vessel sea base concepts and for evaluating traditional cargo transfer operations.

TECHNICAL AND COST FEASIBILITY

An independent group of marine experts from industry, the American Bureau of Shipping and academia reviewed the MOB program (Cheung and Slaughter, 1999). They found that a CTOL-capable MOB is feasible, pending confirmation of satisfactory global response. A shorter VTOL-capable MOB is feasible now (Taylor and Palo, 2000).

Estimating the cost of a novel structure such as MOB is difficult, especially when user requirements are, at best, approximate. The four concept designers provided cost estimates ranging from 5 to 10 billion dollars for a basic 1500-meter-long MOB, built to commercial standards. Not all the designs were equal and some estimates included design and facilities costs. Also, some concepts provided up to 350% more storage volume than required for most military missions. This was because each module was identically configured to support all logistics functions, rather than sharing these functions across all modules.

The cost of a single nominal 350-meter-long "logistics" module is estimated to cost approximately 1.5 billion dollars. Placed outboard of the "logistics" modules to extend platform length to accommodate CTOL aircraft, a simpler "runway" module (with no significant cargo storage) costs substantially less.

The cost of a single MOB semisubmersible module is comparable to the cost of a single, conventional, amphibious ships (such as the LHD), which may have ¼ the cargo volume of a single MOB module. However, it is most appropriate to compare MOB to a land base, since MOB is a replacement for, or at least a complement to foreign land bases. In addition, a MOB avoids the unrecoverable costs associated with building and abandoning temporary land bases. How many land bases equate to a MOB that can easily be relocated during its 40-year design life? We need to look back only a few years for the number of times the US has built a forward land base to support its allies only to abandon that base a few years later. In fact, MOB represents a new type of rapidly relocateable "read-to-use" base whose true benefit is hard to quantify, since no such asset has come before it.

UNFINISHED BUSINESS

Some of the remaining major issues that were not resolved due to insufficient time and are recommended for further study are listed below:

- ***Global response evaluation***. Significant improvements were made to hydrodynamic and hydroelastic analyses models and laboratory-scale hydroelastic tests were completed. However, the models need to be validated against the test data.

- ***Cargo Transfer***. Additional research work is required to identify and improve the ability of cargo handling equipment to transfer cargo to and from MOB and to develop concepts for rapid transfer of material from MOB to shore.

- ***Classification Guide***. Further development of the Guide is necessary to quantify many of the parameters, such as the partial safety factors. In addition, the final Guide needs to be fully exercised for a representative platform design.

- ***Dynamic Positioning***. The effort in multi-module dynamic positioning needs to continue, with an emphasis on failure tolerance and reliability.

- ***Connectors***. Trading increased relative motions for greatly reduced loads, flexible connectors are feasible. However, these new-generation compliant connectors need to be demonstrated at operational scale.

- ***Metocean Environmental Specification***. Completion of pioneering studies in large-scale wave coherence is absolutely necessary in order to get accurate force maximum and fatigue estimates for elastic connector design.

RELEVANCE OF MOB TECHNOLOGY

As described above, the ONR MOB Program has made fundamental advancements regarding the technologies associated with very large offshore structures. For example, potential mission requirements have been deconstructed into design criteria supplemented with specific studies to define parameters such as airfield and cargo requirements, speed, size, and general configuration. An environmental specification and a fundamental design procedure were developed to ensure structural reliability. Furthermore, hydrodynamic analysis tools have been developed or improved, although they need to be validated against scale-model tests. Viable construction procedures have been advanced and are determined to be within the capabilities of the shipbuilding industry.

While system studies were directed towards MOB and its semisubmersible hull form, all of the tools and methodologies are deliberately independent of the hull form and the military logistics mission. MOB technologies can be readily applied to other military and commercial offshore missions and the various types of large offshore structures that would result.

One of the primary reasons for considering moving certain facilities offshore is congestion. Seventy five percent of the US population lives within 50 miles of the coasts or Great Lakes, placing strong demands on often expensive, environmentally sensitive and otherwise cherished land resources. As such, offshore options are becoming both economically and politically viable for satisfying many military and commercial missions. For many of these potential missions, the offshore facilities (for example airports, seaports, industrial plants, and aquaculture farms) often require offshore platforms that are both large and innovative, not unlike that required for a MOB. Let's look at a few such offshore facilities that are under active consideration.

OFFSHORE TRAINING PLATFORM

Carrier aviation requires precision flying skills that must be routinely practiced in a realistic environment. Consequently for Navy fleet readiness, there is a growing need for aircrew touch-and-go training platforms positioned offshore near key Navy airfield installations. MOB technology

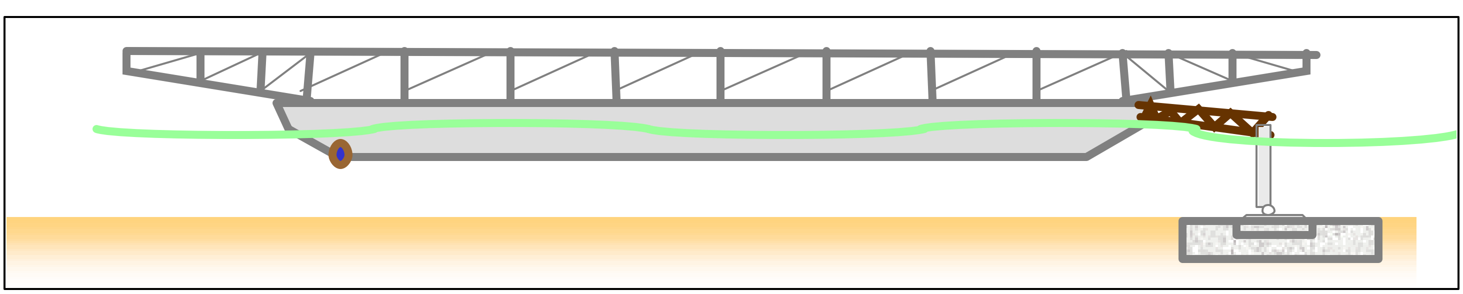

Figure 5. Concept for an offshore training platform

is useful for designing, building and operating these unprecedented offshore training platforms. A single semisubmersible (or barge-like) module, no longer than 500 meters, appears sufficient for a touch-and-go runway at sea. This simple runway module would be positioned using at a single point mooring and suction pile anchor as shown in Figure 5.

Using thrusters, one could orient the runway into the wind for optimal fixed-wing aircraft landing and takeoff or at various other approaches to the wind for testing aircrew abilities. Designed to last 50 years, the offshore training platform would either survive all expected storms on-site, or be disconnected and moved to a sheltered site.

COMMERCIAL OFFSHORE AIRFIELDS

Locating land for new airports that are convenient to the metropolitan areas but that are sufficiently remote to avoid jet noise is difficult. Large fixed, floating steel mat-type structures are now becoming available for siting airports in protected waters (Sueoka & Sato, 2000). Fixed or mobile semisubmersible-type structures like MOB may be more appropriate for unprotected waters.

In fact, a mobile offshore airport like MOB has been suggested as a possible airport hub for express mail shipment. For example, a MOB strategically located in the Pacific Ocean could service all the Pacific rim economies with one-day delivery. Depending on seasonal demand, the MOB could be easily moved to an optimal location in the Pacific Ocean where fuel costs are minimized for all incoming and outgoing aircraft. In addition, offshore airfields have been suggested to serve major oil and gas fields in the North Sea, Labrador Sea and Gulf of Mexico. These CTOL capable offshore airfields are suggested for reducing the number of more dangerous and lengthy helicopter transits.

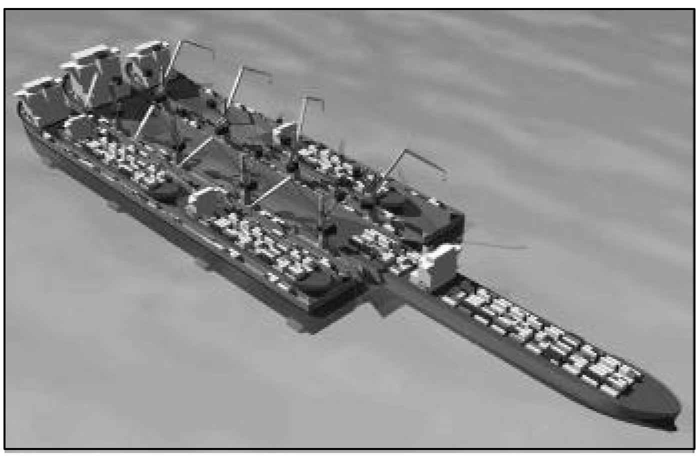

Figure 6. Concept for a commercial offshore port.
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COMMERCIAL OFFSHORE PORTS

There is a need for offshore ports to support larger, deeper-draft vessels and the vastly increased flow of sea cargo. Existing port facilities and their related rail hubs are operating at or above design capacities. Expansion of these facilities is complicated by the huge cost of expanding the channels and harbors by dredging and treating the spoils. An offshore facility combined with smaller, channel and port-friendly, vessels can eliminate dredging costs, relieve congestion, speed delivery, and enable areas with limited facilities to receive cargo using existing shuttle assets.

Dealing directly with the open-ocean cargo transfer problem, Figure 6 shows a concept for a commercial offshore port. This floating port consists of three large dock ships connected together to allow transfer of cargo from the very large cargo ship in the center to smaller vessels on the outside. Using MOB developed-connectors on the sides of the dock ships, this offshore port would function as a regional transshipment node and could be moved to respond to changing needs and storm conditions.

Given the apparent need for offshore facilities, why then has one not been built? The answer was high cost and unacceptable risk associated with an inadequate design capability and the lack of experience. However, recent environmental compliance requirements have driven up the cost of dredging and related items to a level where floating options may now be relatively competitive. Also, offshore technology, particularly for semisubmersible platforms, has matured tremendously in the past few years to a point where the risk may have been reduced to an acceptable level.

CONCLUSIONS

The key technology issues that put MOB beyond the state of practice will be resolved with completion of the few remaining science and technology efforts. Provided that future hydrodynamic analysis using large-scale wave characteristics confirms satisfactory platform responses, it is concluded that the use of a MOB in the open ocean as a forward base is technically feasible. This conclusion of feasibility applies to a MOB ranging from one 300-meter long semisubmersible module to a 2-kilometer long platform consisting of serially connected modules.

There is no single definition of a “Mobile Offshore Base,” rather it is a collection of many possible platform configurations and lengths comprised of one or multiple modules (either identical or different). This provides flexibility in meeting particular mission requirements for both military and civilian users.

There are many potential applications for very large floating structures like a MOB. We introduced a few in this paper, and leave it to the reader to develop new ones. Our focus in the MOB Program was to develop the technology that ensures that a very-large, mobile floating structure could be advanced with confidence. Given the resulting risk reduction, the question is no longer, “Will one be built?” but rather, “When will one be built?”

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